



wherein  $R^4$  is a group or an atom selected from a  $C_{1-20}$  hydrocarbon group, a hydrogen atom and a halogen atom,  $R^5$  is a  $C_{1-20}$  hydrocarbon group, Z is a heteroatom or a heteroatom-containing group, and W is a polymer chain obtained by (co)polymerizing an addition-polymerizable monomer (D), a ring-opening polymerizable monomer (E) and at least one monomer selected from polyolefin macromonomers (M1) to (M3) represented by the general formulae (V) to (VII).

The polar polymer chain (A3) contained in the multi-branched polymer according to the present invention is obtained by polymerizing an addition-polymerizable monomer (D) or a ring-opening polymerizable monomer (E).

The thermoplastic resin composition according to the present invention comprises the above-described multi-branched polymer, and is employed in various applications.

Further, the present invention relates to a film, a sheet, an adhesive resin, a compatibilizing agent, a resin modifier, a resin additive, a filler dispersant or a dispersant, which comprises the above-described multi-branched polymer.

Further, the present invention relates to a film, a sheet, an adhesive resin, a compatibilizing agent, a resin modifier, a resin additive, a filler dispersant or a dispersant, which comprises the above-described thermoplastic resin composition.

### Brief Description of Drawings

Fig. 1-1 shows the multi-branched polymer of the general formula (II) wherein  $P^2$  is the polar polymer chain having polyolefin side chains (A4), and  $P^3$  is the polyolefin chain (A1).

Fig. 1-2 shows the multi-branched polymer of the general formula (II) wherein  $P^2$  is the polar polymer chain having polyolefin side chains (A4), and  $P^3$  is the polyolefin chain having polar polymer side chains (A2).

Fig. 1-3 shows the multi-branched polymer of the general formula (II) wherein  $P^2$  is the polar polymer chain having polyolefin side chains (A4), and  $P^3$  is the polar polymer chain (A3).

Fig. 1-4 shows the multi-branched polymer of the general formula (II) wherein  $P^2$  is the polar polymer chain having polyolefin side chains (A4), and  $P^3$  is the polar polymer chain having polyolefin side chains (A4).

Fig. 2-1 shows the multi-branched polymer of the general formula (III) wherein two  $P^5$ s are each the polyolefin chain (A1).

Fig. 2-2 shows the multi-branched polymer of the general formula (III) wherein two  $P^5$ s are each the polar polymer chain (A3).

Fig. 2-3 shows the multi-branched polymer of the general formula (III) wherein two  $P^5$ s are each the polar polymer chain having polyolefin side chains (A4).

Fig. 2-4 shows the multi-branched polymer of the general formula (III) wherein one of two  $P^5$ s is the polyolefin chain

(A1), and the other is the polar polymer chain (A3).

Fig. 2-5 shows the multi-branched polymer of the general formula (III) wherein one of two  $P^5$ 's is the polyolefin chain (A1), and the other is the polar polymer chain having polyolefin side chains (A4).

Fig. 2-6 shows the multi-branched polymer of the general formula (III) wherein one of two  $P^5$ 's is the polar polymer chain (A3), and the other is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-1 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and all of three  $P^6$ 's are each the polyolefin chain (A1).

Fig. 3-2 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and all of three  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-3 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polyolefin chain (A1), and the remainder is the polar polymer chain (A3).

Fig. 3-4 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polyolefin chain (A1), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-5 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polar polymer chain (A3), and the remainder is the polyolefin chain (A1).

Fig. 3-6 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polar polymer chain (A3), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-7 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polyolefin chain (A1).

Fig. 3-8 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and two of three  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polar polymer chain (A3).

Fig. 3-9 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 3, and one of three  $P^6$ 's is the polyolefin chain (A1), another one is the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-10 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and all of four  $P^6$ 's are each the polyolefin chain (A1).

Fig. 3-11 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and all of four  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-12 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polyolefin chain (A1), and the remainder is the polar polymer chain (A3).

Fig. 3-13 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polyolefin chain (A1), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-14 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polar polymer chain (A3), and the remainder is the polyolefin chain (A1).

Fig. 3-15 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polar polymer chain (A3), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-16 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polyolefin chain (A1).

Fig. 3-17 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and three of four  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polar polymer chain (A3).

Fig. 3-18 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polyolefin chain (A1), and the remaining two are each the polar polymer chain (A3).

Fig. 3-19 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polyolefin chain (A1), and the remaining two are each the polar

polymer chain having polyolefin side chains (A4).

Fig. 3-20 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polyolefin chain (A1), another one is the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-21 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polar polymer chain (A3), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-22 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polar polymer chain (A3), another one is the polyolefin chain (A1), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-23 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 4, and two of four  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), another one is the polyolefin chain (A1), and the last one is the polar polymer chain (A3).

Fig. 3-24 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and all of five  $P^6$ 's are each the polyolefin chain (A1).

Fig. 3-25 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and all of five  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-26 shows the multi-branched polymer of the general

formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polyolefin chain (A1), and the remainder is the polar polymer chain (A3).

Fig. 3-27 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polyolefin chain (A1), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-28 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polar polymer chain (A3), and the remainder is the polyolefin chain (A1).

Fig. 3-29 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polar polymer chain (A3), and the remainder is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-30 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polyolefin chain (A1).

Fig. 3-31 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and four of five  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), and the remainder is the polar polymer chain (A3).

Fig. 3-32 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ s are each the polyolefin chain (A1), and the remaining two are each the polar polymer chain (A3).

Fig. 3-33 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polyolefin chain (A1), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-34 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polyolefin chain (A1), another one is the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-35 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polar polymer chain (A3), and the remaining two are each the polyolefin chain (A1).

Fig. 3-36 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polar polymer chain (A3), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-37 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polar polymer chain (A3), another one is the polyolefin chain (A1), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-38 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the remaining two are each the polyolefin chain (A1).

Fig. 3-39 shows the multi-branched polymer of the general



formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), and the remaining two are each the polar polymer chain (A3).

Fig. 3-40 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and three of five  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), another one is the polyolefin chain (A1), and the last one is the polar polymer chain (A3).

Fig. 3-41 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and two of five  $P^6$ s are each the polyolefin chain (A1), other two are each the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-42 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and two of five  $P^6$ s are each the polyolefin chain (A1), other two are each the polar polymer chain having polyolefin side chains (A4), and the last one is the polar polymer chain (A3).

Fig. 3-43 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 5, and two of five  $P^6$ s are each the polar polymer chain (A3), other two are each the polar polymer chain having polyolefin side chains (A4), and the last one is the polyolefin chain (A1).

Fig. 3-44 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and all of six  $P^6$ s are each the polyolefin chain (A1).

Fig. 3-45 shows the multi-branched polymer of the general

formula (IV) wherein  $n'$  is 6, and all of six  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-46 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polyolefin chain (A1), and the last one is the polar polymer chain (A3).

Fig. 3-47 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polyolefin chain (A1), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-48 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polar polymer chain (A3), and the last one is the polyolefin chain (A1).

Fig. 3-49 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-50 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the last one is the polyolefin chain (A1).

Fig. 3-51 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and five of six  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), and the last one is the polar polymer chain (A3).

Fig. 3-52 shows the multi-branched polymer of the general

formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polyolefin chain (A1), and the remaining two are each the polar polymer chain (A3).

Fig. 3-53 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polyolefin chain (A1), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-54 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polyolefin chain (A1), another one is the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-55 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polar polymer chain (A3), and the remaining two are each the polyolefin chain (A1).

Fig. 3-56 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polar polymer chain (A3), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-57 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the polar polymer chain (A3), another one is the polyolefin chain (A1), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-58 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ 's are each the

polar polymer chain having polyolefin side chains (A4), and the remaining two are each the polyolefin chain (A1).

Fig. 3-59 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), and the remaining two are each the polar polymer chain (A3).

Fig. 3-60 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and four of six  $P^6$ s are each the polar polymer chain having polyolefin side chains (A4), another one is the polyolefin chain (A1), and the last one is the polar polymer chain (A3).

Fig. 3-61 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ s are each the polyolefin chain (A1), and the remaining three are each the polar polymer chain (A3).

Fig. 3-62 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ s are each the polyolefin chain (A1), and the remaining three are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-63 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ s are each the polyolefin chain (A1), other two are each the polar polymer chain (A3), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-64 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ s are each the polyolefin chain (A1), other two are each the polar polymer chain

having polyolefin side chains (A4), and the last one is the polar polymer chain (A3).

Fig. 3-65 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ 's are each the polar polymer chain (A3), and the remaining three are each the polar polymer chain having polyolefin side chains (A4).

Fig. 3-66 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ 's are each the polar polymer chain (A3), other two are each the polyolefin chain (A1), and the last one is the polar polymer chain having polyolefin side chains (A4).

Fig. 3-67 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ 's are each the polar polymer chain (A3), other two are each the polar polymer chain having polyolefin side chains (A4), and the last one is the polyolefin chain (A1).

Fig. 3-68 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), other two are each the polyolefin chain (A1), and the last one is the polar polymer chain (A3).

Fig. 3-69 shows the multi-branched polymer of the general formula (IV) wherein  $n'$  is 6, and three of six  $P^6$ 's are each the polar polymer chain having polyolefin side chains (A4), other two are each the polar polymer chain (A3), and the last one is the polyolefin chain (A1).

Fig. 3-70 shows the multi-branched polymer of the general

formula (IV) wherein  $n'$  is 6, and two of six  $P^6$ s are each the polyolefin chain (A1), other two are each the polar polymer chain (A3), and the remaining two are each the polar polymer chain having polyolefin side chains (A4).

Fig. 4 shows a TEM image of a four-arm (PMMA-g-EPR) star-shaped polymer.

Fig. 5 shows a TEM image of an EPR/PMMA blend.

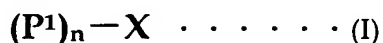
Fig. 6 shows a TEM image of a PMMA-g-EPR graft polymer.

#### Best Mode for Carrying out the Invention

The multi-branched polymer of the present invention and applications thereof are described in detail by reference to the best mode thereof.

#### [1] Multi-branched polymer and units constituting the same

The multi-branched polymer according to the present invention is a multi-branched polymer containing a block structure, a graft structure or a star-shaped structure, which is represented by the general formula (I):



wherein  $P^1$  is a polymer chain having a number-average molecular weight ( $M_n$ ) of 500 to 1,000,000, selected from a polyolefin chain (A1), a polyolefin chain having polar polymer side chains (A2), a polar polymer chain (A3) and a polar polymer chain having polyolefin side chains (A4) whereupon a plurality of  $P^1$ s may be the same or different from one another provided that every  $P^1$  shall not be the polar polymer chain (A3); when  $n$  is 2, at

least one  $P^1$  is the polar polymer chain having polyolefin side chains (A4); and X is a heteroatom or a heteroatom-containing linking group containing less than 200 atoms in total.

Hereinafter, the polymer chain  $P^1$  is described.

In the formula (I), the polymer chain  $P^1$  has a number-average molecular weight ( $M_n$ ) of 500 to 1,000,000, and is selected from a polyolefin chain (A1), a polyolefin chain having polar polymer side chains (A2), a polar polymer chain (A3) and a polar polymer chain having polyolefin side chains (A4).

The multi-branched polymer of the present invention is a polymer composed of a plurality of polymer chain  $P^1$ 's selected from the polyolefin chain (A1), the polyolefin chain having polar polymer side chains (A2), the polar polymer chain (A3) and the polar polymer chain having polyolefin side chains (A4).

First, the 4 kinds of polymer chains constituting the multi-branched polymer of the present invention are described in detail.

#### [1-1] Polyolefin chain (A1)

The polyolefin chain (A1) represents a residue of polyolefin ( $P-H$  wherein  $P$  is a polyolefin chain, and  $H$  is a hydrogen atom) obtained by (co)polymerizing one or more olefins represented by formula (X) below in the presence of a coordination polymerization catalyst containing compounds of the groups 4 to 11 transition metals in the periodic table. For example, the polyolefin residue in the case where ethylene polymerization proceeds ideally without forming a branched chain is represented by  $CH_3-(CH_2)_n-$ .



wherein  $R^3$  represents a  $C_{1-20}$  hydrocarbon group, a hydrogen atom or a halogen atom.

The  $C_{1-20}$  hydrocarbon group includes, for example, a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, octyl group, decyl group etc. The olefins represented by the formula (X) above include, for example,  $C_{4-20}$  linear or branched  $\alpha$ -olefins such as ethylene, propylene, 1-butene, 1-pentene, 3-methyl-1-butene, 1-hexene, 4-methyl-1-pentene, 3-methyl-1-pentene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicocene; and vinyl halides such as vinyl chloride and vinyl bromide. Preferably used among these exemplary olefins are one or more olefins selected from ethylene, propylene, 1-butene, 1-hexene and 1-octene, particularly preferably ethylene alone, propylene alone, both propylene and ethylene, both ethylene and 1-butene, or both propylene and 1-butene, which are (co)polymerized to prepare the polyolefin chain.

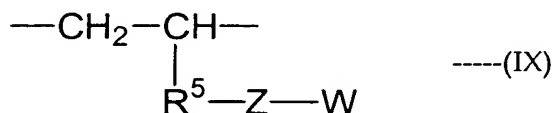
The number-average molecular weight ( $M_n$ ) of the polyolefin chain (A1) is substantially equal to the  $M_n$  of its corresponding polyolefin (P-H), and from the viewpoint of balance between usefulness in physical properties of the multi-branched polymer of the present invention and a polyolefin segment in a resin composition containing the multi-branched polymer and the reactivity of the multi-branched polymer during production, the  $M_n$  is usually in the range of 500 to 10,000,000, preferably 500



to 500,000, particularly preferably 500 to 300,000.

[1-2] Polyolefin chain having polar polymer side chains (A2)

The polyolefin chain having polar polymer side chains (A2) is a polymer chain comprising a unit (C1) represented by the formula (VIII) and a unit (C2) represented by the formula (IX).

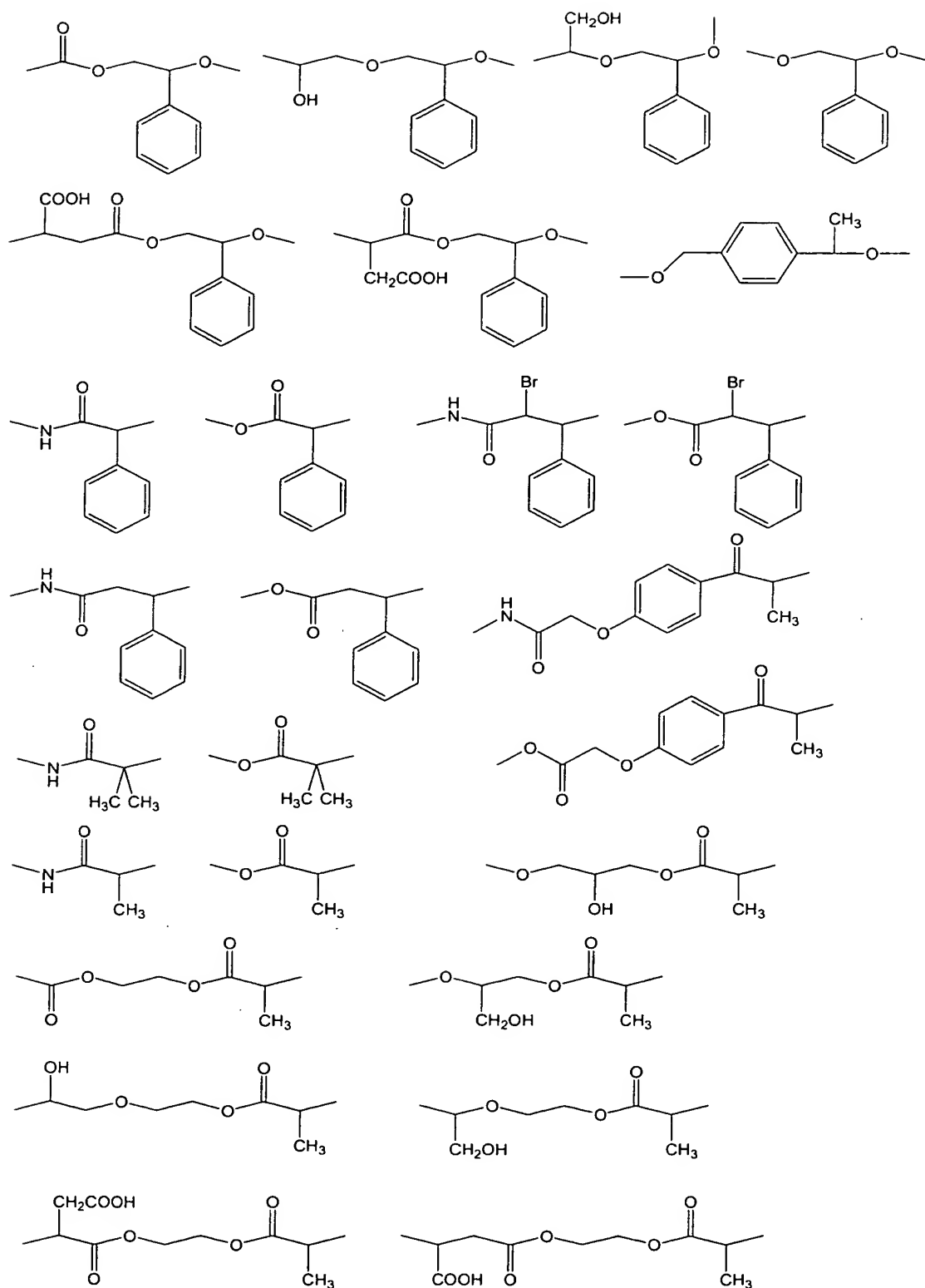


In the formula (VIII),  $\text{R}^4$  is an atom or a group selected from a  $\text{C}_{1-20}$  hydrocarbon group, a hydrogen atom or a halogen atom, and the  $\text{C}_{1-20}$  hydrocarbon group includes, for example, a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, octyl group, decyl group etc.

In the formulae (IX),  $\text{R}^5$  is a  $\text{C}_{1-20}$  hydrocarbon group, Z is a heteroatom or a heteroatom-containing group, and W is a polymer chain obtained by (co)polymerizing an addition-polymerizable monomer (D), a ring-opening-polymerizable monomer (E) and at least one monomer selected from polyolefin macromonomers (M1) to (M3) represented by the general formulae (V) to (VII).

The number-average molecular weight ( $M_n$ ) of the polyolefin chain (A2) is usually in the range of 500 to 10,000,000, preferably 500 to 500,000, particularly preferably 500 to 300,000. The

heteroatom or the heteroatom-containing group represented by Z is specifically a group containing a group selected from an ester group, an ether group and an amide group. Specific structural formulae of Z are as follows:



The polymer chain represented by W includes a polymer obtained by (co)polymerizing an addition-polymerizable monomer

(D), a ring-opening-polymerizable monomer (E) and at least one monomer selected from polyolefin macromonomers (M1) to (M3) represented by the general formulae (V) to (VII).

The addition-polymerizable monomer (D) is selected from organic compounds each having at least one carbon-carbon unsaturated bond. The carbon-carbon unsaturated bond is a carbon-carbon double bond or a carbon-carbon triple bond. Examples of such organic compounds include (meth)acrylate monomers such as (meth)acrylic acid, methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, isopropyl (meth)acrylate, n-butyl (meth)acrylate, isobutyl (meth)acrylate, tert-butyl (meth)acrylate, n-pentyl (meth)acrylate, n-hexyl (meth)acrylate, cyclohexyl (meth)acrylate, n-heptyl (meth)acrylate, n-octyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, nonyl (meth)acrylate, decyl (meth)acrylate, dodecyl (meth)acrylate, phenyl (meth)acrylate, toluyl (meth)acrylate, benzyl (meth)acrylate, 2-methoxyethyl (meth)acrylate, 3-methoxybutyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, stearyl (meth)acrylate, glycidyl (meth)acrylate, 2-aminoethyl (meth)acrylate,  $\gamma$ -(methacryloyloxypropyl) trimethoxy silane, (meth)acrylic acid/ethylene oxide adducts, trifluoromethylmethyl (meth)acrylate, 2-trifluoromethylethyl (meth)acrylate, 2-perfluoroethylethyl (meth)acrylate, 2-perfluoroethyl-2-perfluorobutylethyl (meth)acrylate, 2-perfluoroethyl (meth)acrylate, perfluoromethyl

(meth)acrylate, diperfluoromethylmethyl (meth)acrylate, 2-perfluoromethyl-2-perfluoroethylmethyl (meth)acrylate, 2-perfluorohexylethyl (meth)acrylate, 2-perfluorodecylethyl (meth)acrylate and 2-perfluorohexadecylethyl (meth)acrylate, styrene monomers such as styrene, vinyl toluene,  $\alpha$ -methylstyrene, chlorostyrene, styrenesulfonic acid and salts thereof, fluorine-containing vinyl monomers such as perfluoroethylene, perfluoropropylene and vinylidene fluoride, silicon-containing vinyl monomers such as vinyltrimethoxy silane and vinyltriethoxy silane, maleimide monomers such as maleic anhydride, maleic acid, monoalkyl and dialkyl maleates, fumaric acid, monoalkyl and dialkyl fumarates, maleimide, methyl maleimide, ethyl maleimide, propyl maleimide, butyl maleimide, hexyl maleimide, octyl maleimide, dodecyl maleimide, stearyl maleimide, phenyl maleimide and cyclohexyl maleimide, nitrile group-containing vinyl monomers such as acrylonitrile and methacrylonitrile, amide group-containing vinyl monomers such as (meth)acrylamide, N-methyl (meth)acrylamide, N-ethyl (meth)acrylamide, N-propyl (meth)acrylamide, N-isopropyl (meth)acrylamide and N-butyl (meth)acrylamide, vinyl ester monomers such as vinyl acetate, vinyl propionate, vinyl pivalate, vinyl benzoate and vinyl cinnamate, olefinic monomers such as ethylene, propylene and butene, diene monomers such as butadiene and isoprene, vinyl ether monomers such as ethyl vinyl ether and isopropyl vinyl ether, and N-vinyl carbazole, indene, isobutene, vinyl chloride, vinylidene chloride, allyl chloride and allyl alcohol. These organic compounds may be used alone or in combination thereof.

The ring-opening-polymerizable monomer (E) includes oxysilane compounds and lactone compounds. Specific examples include oxysilane compounds such as ethylene oxide, propylene oxide, butylene oxide, styrene oxide and epichlorohydrin, and lactone compounds such as  $\beta$ -propiolactone,  $\alpha,\alpha$ -bis(chloromethyl)- $\beta$ -propiolactone,  $\beta$ -butyrolactone,  $\delta$ -valerolactone, 1,4-dioxan-2-one, glycoside, lactide, trimethylene carbonate and  $\epsilon$ -caprolactone.

The polyolefin macromonomers (M1) to (M3) represented by the general formulae (V) to (VII) include macromonomers produced by the same method as in production of polyolefin macromonomers used in producing the polar polymer having a polyolefin side chain (A4) as described later.

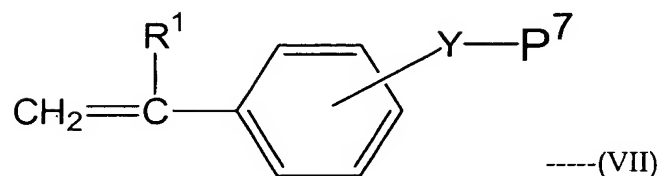
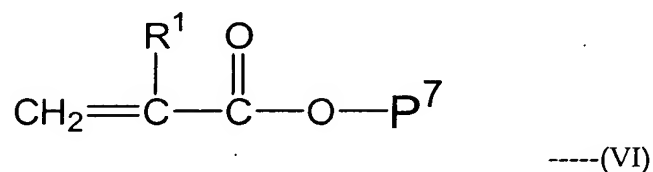
[1-3] Polar polymer chain (A3)

The polar polymer chain (A3) includes a polymer chain obtained by polymerizing the addition-polymerizable monomer (D) or the ring-opening polymerizable monomer (E). The number-average molecular weight ( $M_n$ ) of the polar polymer chain (A3) is usually in the range of 500 to 10,000,000, preferably 500 to 500,000, particularly preferably 500 to 300,000.

[1-4] Polar polymer chain having polyolefin side chains (A4)

The polar polymer chain having polyolefin side chains (A4) is obtained by homopolymerizing a macromonomer, or copolymerizing two or more macromonomers, selected from the polyolefin macromonomer (M1) represented by the general formula (V), the polyolefin macromonomer (M2) represented by the general formula (VI) and the polyolefin macromonomer (M3) represented

by the general formula (VII), or by copolymerizing at least one macromonomer selected from (M1), (M2) and (M3) with at least one monomer (B) selected from organic compounds each having at least one carbon-carbon unsaturated bond, and the number-average molecular weight ( $M_n$ ) of the polar polymer chain having polyolefin side chains (A4) is usually in the range of 500 to 10,000,000, preferably 500 to 500,000, particularly preferably 500 to 300,000.



In the formulae (V) to (VII),  $\text{R}^1$  is a hydrogen atom or a methyl group, and Y is a heteroatom or a heteroatom-containing group which is specifically a linking group containing a group selected from an ester group, an amide group and an ether group.

Specific examples of Y include groups presented by the

following chemical formulae: ether linkage-containing groups such as  $-O-CH_2-$ ,  $-O-(CH_2)_2-$ ,  $-O-(CH_2)_3-$ ,  $-O-CH(CH_3)-CH_2-$ ,  $-O-CH_2-CH(CH_3)-$ ,  $-O-(CH_2)_4-$ ,  $-O-CH_2-CH(OH)-$ ,  $-O-CH_2-CH(OH)-CH_2-$ ,  $-O-CH_2-CH(OH)-(CH_2)_2-$ ,  $-O-CH_2-CH(OH)-(CH_2)_3-$ ,  $-O-CH_2-CH(OH)-(CH_2)_4-$ ,  $-O-CH_2-CH(OH)-CH_2-O-CH_2-$ ,  $-O-CH(CH_2OH)-$ ,  $-O-CH(CH_2OH)-CH_2-$ ,  $-O-CH(CH_2OH)-(CH_2)_2-$ ,  $-O-CH(CH_2OH)-(CH_2)_3-$ ,  $-O-CH(CH_2OH)-(CH_2)_4-$ ,  $-O-CH(CH_2OH)-CH_2-O-CH_2-$ ,  $-CH(OH)-CH_2-O-$ ,  $-CH(OH)-CH_2-O-CH_2-$ ,  $-CH(OH)-CH_2-O-(CH_2)_2-$ ,  $-CH(OH)-CH_2-O-(CH_2)_3-$ ,  $-CH(OH)-CH_2-O-(CH_2)_4-$ ,  $-CH(CH_2OH)-O-$ ,  $-CH(CH_2OH)-O-CH_2-$ ,  $-CH(CH_2OH)-O-(CH_2)_2-$ ,  $-CH(CH_2OH)-O-(CH_2)_3-$  and  $-CH(CH_2OH)-O-(CH_2)_4-$ ; carboxylate-containing groups such as  $-(CO)O-$ ,  $-(CO)O-CH_2-$ ,  $-(CO)O-(CH_2)_2-$ ,  $-(CO)O-(CH_2)_3-$ ,  $-(CO)O-(CH_2)_4-$ ,  $-O(CO)-$ ,  $-O(CO)-CH_2-$ ,  $-O(CO)-(CH_2)_2-$ ,  $-O(CO)-(CH_2)_3-$ ,  $-O(CO)-(CH_2)_4-$ ,  $-(CO)O(CO)-$ ,  $-(CO)O(CO)-CH_2-$ ,  $-(CO)O(CO)-(CH_2)_2-$ ,  $-(CO)O(CO)-(CH_2)_3-$ ,  $-(CO)O(CO)-(CH_2)_4-$ ,  $-C(COOH)-CH_2-(CO)O-$ ,  $-C(COOH)-CH_2-(CO)O-CH_2-$ ,  $-C(COOH)-CH_2-(CO)O-(CH_2)_2-$ ,  $-C(COOH)-CH_2-(CO)O-(CH_2)_3-$ ,  $-C(CH_2COOH)-(CO)O-$ ,  $-C(CH_2COOH)-(CO)O-CH_2-$ ,  $-C(CH_2COOH)-(CO)O-(CH_2)_2-$  and  $-C(CH_2COOH)-(CO)O-(CH_2)_3-$ ; amide-containing groups such as  $-NH(CO)-$ ,  $-NH(CO)-CH_2-$ ,  $-NH(CO)-(CH_2)_2-$ ,  $-NH(CO)-(CH_2)_3-$ ,  $-NH(CO)-(CH_2)_4-$ ,  $-(CO)NH-$ ,  $-(CO)NH-CH_2-$ ,  $-(CO)NH-(CH_2)_2-$ ,  $-(CO)NH-(CH_2)_3-$  and  $-(CO)NH-(CH_2)_4-$ ; and carbamate-containing groups such as  $-O(CO)NH-$ ,  $-O(CO)NH-CH_2-$ ,  $-O(CO)NH-(CH_2)_2-$ ,  $-O(CO)NH-(CH_2)_3-$  and  $-O(CO)NH-(CH_2)_4-$ .

$P^7$  is a polymer chain obtained by homopolymerizing or copolymerizing olefins represented by  $CH_2=CHR^2$  wherein  $R^2$  is a



group or an atom selected from a C<sub>1-20</sub> hydrocarbon group, a hydrogen atom and a halogen atom.

Hereinafter, the polyolefin macromonomers (M1), (M2) and (M3) serving as the starting material of the polar polymer chain having polyolefin side chains (A4) are described in detail.

[1-4a] Polyolefin macromonomer (M1)

The polyolefin macromonomer (M1) represented by the general formula (V) is a polyolefin macromonomer having a vinyl group or a vinylidene group at the terminal thereof, and for example, the macromonomer (M1) can be produced by homopolymerizing or copolymerizing olefins represented by the above-mentioned CH<sub>2</sub>=CHR<sup>2</sup> in the presence of an olefin polymerization catalyst. The olefin polymerization catalyst used in production of the macromonomer (M1) may be any catalyst known in the art. As the catalyst known in the art, a magnesium-carrying titanium catalyst can be exemplified by a catalyst described in for example EP0641807A, a metallocene catalyst can be exemplified by a catalyst described in for example EP250601A, and a postmetallocene catalyst can be exemplified by a catalyst containing a transition metal complex disclosed in the literatures below. As the compound containing the group 13 element in the periodic table, which constitutes the olefin polymerization catalyst, those compounds described in EP0641807A and EP250601A supra can be used without limitation, but the organoaluminum compound or the organoboron compound is preferably used.

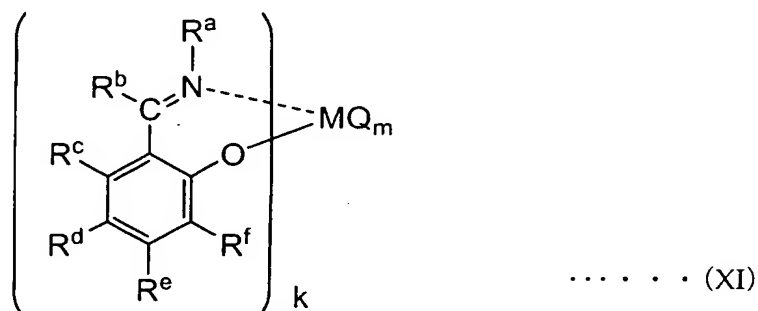
(1) M. Brookhart et al., J. Am. Chem. Soc., 117, 6414 (1995)

(2) D. H. Mc Conville et al., *Macromolecules*, 29, 5241 (1996)

(3) R. H. Grubbs et al., *Organometallics*, 17, 3149 (1998)

(4) EP874005A

As the post-metallocene catalyst, a phenoxyimine compound represented by the general formula (XI), disclosed in EP874005A, is preferably used.



wherein M represents a transition metal atom selected from the groups 3 to 11 metals in the periodic table; k is an integer of 1 to 6; m is an integer of 1 to 6; R<sup>a</sup> to R<sup>f</sup> may be the same or different from one another and each represent a hydrogen atom, a halogen atom, a hydrocarbon group, a heterocyclic compound residue, an oxygen-containing group, a nitrogen-containing group, a boron-containing group, a sulfur-containing group, a phosphorus-containing group, a silicon-containing group, a germanium-containing group or a tin-containing group, among which 2 or more groups may be bound to each other to form a ring; when k is 2 or more, R<sup>a</sup> groups, R<sup>b</sup> groups, R<sup>c</sup> groups, R<sup>d</sup> groups, R<sup>e</sup> groups, or R<sup>f</sup> groups may be the same or different from one another, one group of R<sup>a</sup> to R<sup>f</sup> contained in one ligand and one